



EFFECT OF TILLAGE AND PREPLANT IRRIGATION ON SORGHUM PRODUCTION

R. R. Allen, J. T. Musick
MEMBER MEMBER
ASAE ASAE

ABSTRACT

Reducing irrigation water requirements with furrow irrigation systems is important in the Southern High Plains. Growing grain sorghum, without a preplant irrigation, can potentially reduce irrigation water use and increase crop water use efficiency (WUE), defined as yield/ET. ET includes irrigation, rainfall, and soil water depletion during the crop season. A four-year study was conducted at Bushland, Texas where three tillage methods were evaluated for their effect on off-season soil water storage, furrow irrigation water intake, grain yield, and WUE; both with and without preplant irrigation.

Treatments receiving a preplant (PP) irrigation averaged 483 mm (19 in.) of irrigation intake compared with only 280 mm (11 in.) for the treatments without a preplant irrigation (No-PP). This was a 70% increase in irrigation intake for the PP treatment with only a 10% increase in grain yield. The extra pumping cost for the PP irrigation was about \$10.00/ha (\$4/acre) more than the value of the increased grain yield. Tillage method did not affect over-winter soil water storage and only slightly affected irrigation intake, grain yield, and WUE. Only about 25% of the PP irrigation water intake was recovered in soil water storage. Irrigation intake is defined as the amount applied through graded furrows minus the tailwater runoff. Although the No-PP soil profile averaged 204 mm (8 in.) of soil water in storage (82% of field capacity) to 1.8 m (6 ft) deep, the lack of late April or early May precipitation in two of the four years resulted in a relatively dry seedbed at planting time. Thus, the No-PP irrigation treatment planting was delayed from May until occurrence of early June rainfall. The later planting dates (June 14 and 22) reduced grain yield up to 10%, however, WUE was increased up to 20% by avoiding the preplant irrigation.

INTRODUCTION

Reducing irrigation water requirements and improving crop water use efficiency (WUE) with furrow irrigation is important for the sustainability of irrigated agriculture on the Southern High Plains. Water use efficiency is defined as grain yield/ET. Relatively high energy costs for pumping from the Ogallala Aquifer and reduced well yields from a declining water table have

increased producer interest in improving WUE. Two potential methods of reducing production costs are reduced tillage and eliminating the preplant irrigation. We hypothesized, that through reduced tillage management of crop residue in annual cropping, over-winter soil water recharge would be sufficient to establish grain sorghum without a preplant irrigation. Average precipitation from November through mid-May at Bushland, Texas is 135 mm (5.3 in.).

The advantages for applying preplant irrigations (Musick, 1987) are to:

- Permit early planting without relying on rainfall;
- Delay the need to begin seasonal irrigation;
- Improve soil conditions for seedbed preparation; and
- Germinate crop volunteer and weeds that can be controlled by tillage before planting.

The disadvantages of preplant irrigation are:

- Increased cost of production;
- Increased irrigation water application;
- Reduced WUE; and
- Lower soil temperatures that delay seedling emergence and stand establishment.

The most reliable rainfall period in the Southern High Plains is mid-May to mid-June which coincides with sorghum planting (Musick, 1973, 1985, 1987; Musick et al., 1971). Preplant irrigation amounts are frequently large when applied in graded furrow systems and normally exceed individual irrigation amounts later during the crop season by about 50%. The high preplant irrigation intake rates are related to loosened surface soil conditions from primary tillage, winter frost action, and sometimes by flow retardation from crop residue in reduced tillage systems. Undersander and Regier (1988) reported average preplant furrow irrigation intake of 237 mm (9.3 in.) and 466 mm (18.3 in.), respectively, for fall and spring applications on a fine-textured Sherm silty clay loam near Dumas, Texas. The much greater irrigation application in the spring was attributed to increased intake after winter soil weathering, especially on non-wheel-track furrows.

This study was conducted on a fine-textured and slowly permeable Pullman clay loam (Torrertic Paleustoll) at Bushland, Texas. The soil, described by Unger and Pringle (1981), has a silty clay loam Ap horizon to 150 mm (6 in.) deep, a dense clay B21t horizon from 150 to 400 mm (6 to 16 in.) deep, and a silty clay B22t horizon from 400 to 700 mm (16 in. to 28 in.) deep. Grain sorghum root development, evaluated by soil water extraction, does not extend below the 1.2-m (4-ft) depth in this soil. Maximum plant available soil water storage is about 185 mm (7.3 in.)

Article was submitted for publication in December 1989; reviewed and approved for publication by the Soil and Water Div. of ASAE in April 1990. Presented as ASAE Paper No. 88-2513.

Contribution from USDA Agricultural Research Service, Conservation and Production Research Laboratory, Bushland, TX.

The authors are R. R. Allen, Agricultural Engineer, and J. T. Musick, Agricultural Engineer, USDA-Agricultural Research Service, Conservation and Production Research Laboratory, Bushland, TX.

to this depth (Unger and Pringle, 1981). Preplant irrigations of 150 to 250 mm (6 to 10 in.) intake have been measured with graded furrow application after winter tillage (Musick, 1987). As a result, a preplant irrigation can easily exceed the soil storage capacity available, with the excess lost to deep percolation. The irrigation water could be used more efficiently when applied in seasonal applications after the crop is established. For example, Musick et al. (1971) reported an average of 50 mm (2 in.) of plant available soil water in storage by late spring during a four-year study. Thus, only 135 mm (5.3 in.) of irrigation intake was needed to bring soil water storage to field capacity and the excess would be lost to deep percolation. Intake from succeeding irrigations, following the first application after tillage when the furrow surface has reconsolidated, rarely exceeds 110 mm (4.3 in.). The intake rate of this soil averages only 4.3 mm/h (0.17 in./h) after 5 h and declines to 2.8 mm/h (0.11 in./h) after 10 h (Unger and Pringle, 1981).

When the preplant irrigation was eliminated, Musick (1985) reported that irrigation WUE for sorghum grain production was increased from 1.25 to 1.68 kg/m³ (280 to 380 lb/ac-in.) or 33% in one year and from 1.45 to 2.24 kg/m³ (330 to 510 lb/ac-in.) or 56% in another year. The study indicated that only about 1/3 of the preplant irrigation water was still available in storage at planting. Musick (1987) also reported that the preplant irrigation can constitute about one-third of the total irrigation applied to a grain sorghum crop.

In a four-year study, Musick (1984) reported an average ET of 700 mm (28 in.) to produce 7900 kg/ha (7030 lb/acre) of irrigated grain sorghum. Of this amount, 415 mm (16 in.) was supplied by irrigation, 225 mm (10 in.) by rainfall, and 55 mm (2 in.) by soil profile depletion.

The objectives of this study were to:

- Evaluate the effects of tillage for annual cropping of grain sorghum on soil water storage, irrigation water intake, and WUE, and
- Determine the effect of a preplant irrigation on WUE, stand establishment, plant development, and crop yield.

PROCEDURE

The study was conducted at the USDA Conservation and Production Research Laboratory, Bushland, Texas during the 1984 to 1987 crop seasons. The 4-ha (10 acre) experimental area had standing sorghum residue from a 1983 crop on 0.75-m (30-in.) spaced beds. Three tillage treatments were tested as main plots with two irrigation treatments as subplots. The plot design was randomized block split plot with three replications. Each plot contained twelve 400-m (1320 ft) length furrows on a 0.15% slope. The three tillage treatments were intended to provide a range in tillage intensity and in residue amounts remaining after tillage. Tillage treatments were conventional disking and chiseling (T-1), sweep undercutting (T-2), and a combination chisel-stalk cutting "chisel-chopper" (T-3). The tillage sequences are listed in Table 1. A disk-bedder was used to form beds and furrows. The two irrigation treatments were preplant (PP) and no-preplant (No-PP) applications.

All plots received a fall application of 170 kg/ha (150 lb/acre) of nitrogen as NH₃. Propazine was applied in April

TABLE 1. Tillage sequences used in three treatments at Bushland, TX

Treatments	Season	Operations	
		Pre-plant	No pre-plant
T-1 (conventional)	Fall-Winter	Shred-chisel Multiple diskings Fertilize Bed	Shred-chisel Multiple diskings Fertilize
	Spring	Apply herbicide Roll-cult. beds Irrigation Plant	Apply herbicide Disk Plant flat
T-2 (sweep)	Fall-Winter	Shred-sweep till Fertilize Bed	Shred-sweep till Fertilize
	Spring	Apply herbicide Roll-cult. beds Irrigation Plant	Apply herbicide Sweep cult. Plant flat.
T-3 (chisel-chop)	Fall-Winter	Shred chisel-chop Bed Fertilize	Shred chisel-chop Fertilize
	Spring	Apply herbicide Roll-cult. beds Irrigation Cult.-plant	Apply herbicide Sweep cult. Plant flat

at 3.3 kg/ha (3.0 lb/acre) for weed control. Irrigations were applied through gated pipe and were measured with a propeller meter. Portable calibrated "H" flumes with water level recorders were used to measure irrigation tailwater and storm runoff from four furrows (two wheel-tracked and two non-tracked) per subplot. For preplant applications, furrow inflow rates were set at 0.76 L/sec (12 gal/min) to complete sets in about 24 h while holding tailwater runoff to no more than 15 to 20% of that applied. Preplant gross application depths ranged from 185 to 230 mm (7.3 to 9.1 in.). For seasonal applications, furrow inflow rates were also set at 0.76 L/sec with 12- to 15-h sets used to apply about 100 mm (4 in.). When possible, producers prefer furrow irrigation sets in approximate 12- or 24-h intervals to simplify management. Preplant irrigations were applied on 15 May 1984, 10 May 1985, and 5 May 1986. The preplant irrigation was not applied in 1987 because of wet antecedent soil conditions from spring rainfall.

The PP-subplots were bed-planted in 0.75-m (30-in.) spaced rows on 24 May, 1984, 30 May 1985, and 16 May 1986. The No-PP subplots were managed in a flat surface condition to facilitate stand establishment without a preplant irrigation; and were flat-planted in 0.75-m (30-in.) spaced rows on 22 June 1984, 30 May 1985, 14 June 1986, and 20 May 1987. After flat planting, irrigation furrows were established with a rolling cultivator before the first seasonal irrigation when plants were at about the 8-leaf stage.

Seasonal irrigation was managed for a relatively high yield of 6000 to 8000 kg/ha (5300 to 7100 lb/ac), which required two to four applications, depending upon seasonal rainfall. Dates of seasonal applications are presented in Table 2. Soil water content was measured volumetrically using three cores per plot to 1.8-m (6 ft) deep in 0.3-m (1-ft) increments before and after preplant irrigations, during the early growing season, and at harvest. Crop water use (ET) was determined by the seasonal soil water content

TABLE 2. Post-planting irrigation dates, Bushland, TX (1984-87)

	Irrigation treatments	
	Pre-plant	No pre-plant
1984	12 July	24 July
	15 August	15 August 7 September
1985	10 July	10 July
	24 July	24 July
	13 August	13 August
	2 September	2 September
1986	1 July	17 July
	17 July	1 August
	1 August	
1987		8 July
		22 July

change plus rainfall and irrigation. We assumed that there were no percolation losses after the first irrigation because profile soil water depletion between seasonal irrigations was greater than the irrigation intake amount during succeeding applications. Grain yields were obtained by combine harvesting on 7 November 1984, 29 October 1985, 30 October 1986, and 21 October 1987. Samples were obtained at nine sites in each subplot treatment. Sample areas were four rows wide by 10 m (33 ft) long. Grain yields were adjusted to 14% moisture content.

RESULTS AND DISCUSSION

PRECIPITATION AND CLIMATE EFFECTS

Precipitation received during the study is presented in Table 3. The average May-October growing season precipitation at Bushland, Texas is 367 mm (14.4 in.). The yearly May-October precipitation was 93, 111, 113, and 145% of average for 1984 through 1987, respectively.

In the case of the sorghum crop, the likelihood of precipitation near planting time is important for stand establishment without irrigation. At Amarillo, Texas, [25 km (15 mi) east of Bushland], there is a 60% probability of receiving 80 mm (3.15 in.) of precipitation during the May to 15 June sorghum establishment period (Musick, 1987). The probability of receiving 60 mm (2.36 in.) of precipitation increases to 85% during the same 45-day period (fig. 1).

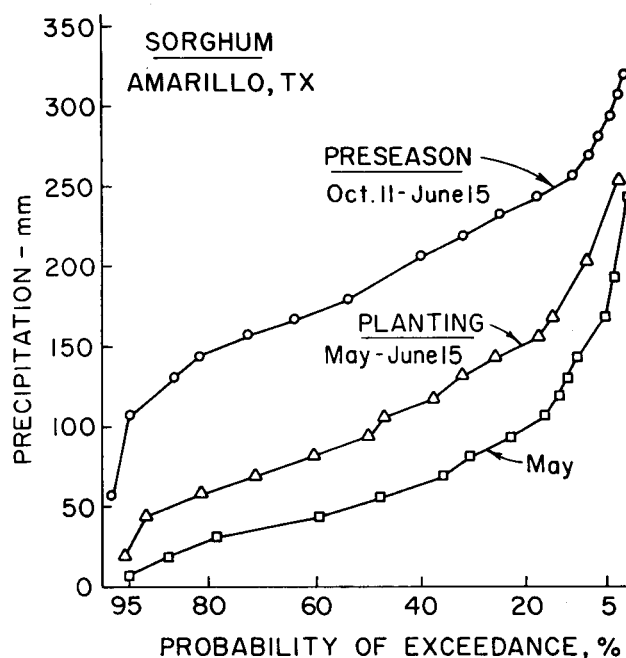


Figure 1—Probability of exceeding precipitation amounts for annually-grown grain sorghum at Amarillo, TX. Totals are for preseason through 15 June planting and for May to 15 June in relation to providing surface soil water for planting (100 mm = 3.94 in.).

The timing of the average late May-early June precipitation peak can shift in individual years such as in 1984 and 1986 when the precipitation peak was delayed about two weeks into June. When this occurs and May precipitation is low, sorghum seeding may need to be delayed until June. The yield potential of grain sorghum decreases when planting is delayed after June 10, but the potential to increase WUE and reduce irrigation cost can offset reduced grain yield.

CULTURAL OPERATIONS

Residue cover after winter tillage averaged 20% on T-1 and 25% on both T-2 and T-3. The relatively small difference in residue cover among tillage treatments was less than expected. After bed-furrow forming followed by bed-furrow cultivation with a rolling cultivator before the preplant irrigation, residue cover was similar (15%) on all tillage treatments.

TABLE 3. Precipitation at research site during preseason and sorghum growing season, Busland, TX (1983-87)

Crop year		Preseason precipitation							Growing season precipitation					Total
		O	N	D	J	F	M	A	M	J	J	A	S	
1983-84	mm	59	6	7	4	---	17	39	---	112	26	113	16	399
	(in.)	(2.32)	(0.24)	(0.28)	(0.16)		(0.67)	(1.53)		(4.41)	(1.02)	(4.45)	(0.63)	(15.7)
1984-85	mm	75	34	23	13	5	36	26	62	41	40	34	172	561
	(in.)	(2.95)	(1.34)	(0.90)	(0.52)	(0.20)	(1.42)	(1.02)	(2.44)	(1.61)	(1.57)	(1.34)	(6.77)	(22.1)
1985-86	mm	62	15	2	---	23	10	5	34	136	26	104	46	463
	(in.)	(2.44)	(0.59)	(0.08)		(0.90)	(0.39)	(0.20)	(1.34)	(5.35)	(1.02)	(4.09)	(1.81)	(18.2)
1986-87	mm	74	43	11	6	26	15	4	141	71	28	126	135	680
	(in.)	(2.91)	(1.69)	(0.43)	(0.24)	(1.02)	(0.59)	(0.16)	(5.55)	(2.80)	(1.10)	(4.96)	(5.31)	(26.8)
49 yr	mm	43	19	14	12	14	20	27	67	76	64	71	46	474
Avg	(in)	(1.69)	(0.75)	(0.55)	(0.470)	(0.55)	(0.79)	(1.06)	(2.64)	(2.99)	(2.52)	(2.80)	(1.81)	(18.7)

In the fourth year, May rainfall, in addition to the winter precipitation, eliminated the need for a preplant irrigation, so all plots were planted flat and furrows were formed during cultivation at about the 8-leaf plant growth stage.

PREPLANT IRRIGATION INTAKE AND STORAGE

The soil water content between fall harvest and the preplant application in the spring varied only slightly between tillage treatments, thus averages of all tillage treatments for each year are presented in figure 2. The preplant irrigation and related soil water content data are presented in Table 4. There was no significant effect by tillage on average preplant irrigation intake and soil water storage, or on irrigation application and storage efficiency during 1984-1986. Preplant irrigation applications averaged 197 mm (7.7 in.) with intake averaging 166 mm (6.5 in.). The preplant application efficiencies averaged 84%. Thus, runoff which averaged 16%, was well within the goal of being held to no more than 15 to 20% of the amount applied.

The relatively low mean storage efficiencies (gain in soil water stored from irrigation/irrigation intake) of preplant irrigation applications averaged only about 25% during 1984 to 1986 and apparently resulted from

1. Favorable over-winter precipitation which brought soil water profile storage to 82% of field capacity,
2. Losses to deep percolation as indicated by figure 2, and

3. Evaporation losses from a slowly permeable, fine-textured soil surface that can remain wet from 3 to 5 days after an irrigation.

PLANTING AND STAND ESTABLISHMENT

In 1984, the absence of precipitation in May (Table 3) delayed planting for the No-PP treatment. On 11 June, a 9-day period of rainfall began totaling 110 mm (4.3 in.) which prevented field re-entry for planting until June 22. The result was a 28-day delay after planting the PP treatment on 24 May. In 1985, May rainfall was near average at 65 mm (2.6 in.), and both PP and No-PP treatments were planted on 30 May because seedbed water content was sufficient for germination. In 1986, PP treatments were ready for planting on 16 May when the No-PP treatment had dry surface soil. Two days later, a 20-day period of rainfall began which totaled 140 mm (5.5 in.). Thus, planting the No-PP treatment was delayed for 28 days until 14 June. In 1987, all plots were flat-planted into a moist seedbed (near field capacity) on 20 May. Satisfactory plant populations were obtained in all years of about 24 plants/m² (2.4 plants/ft²). No tillage treatment effects were observed in seedling emergence, plant population, or early season plant development.

The 28-day delay in planting the No-PP irrigation treatments in two of the four years was longer than normally expected. Planting dates without a preplant

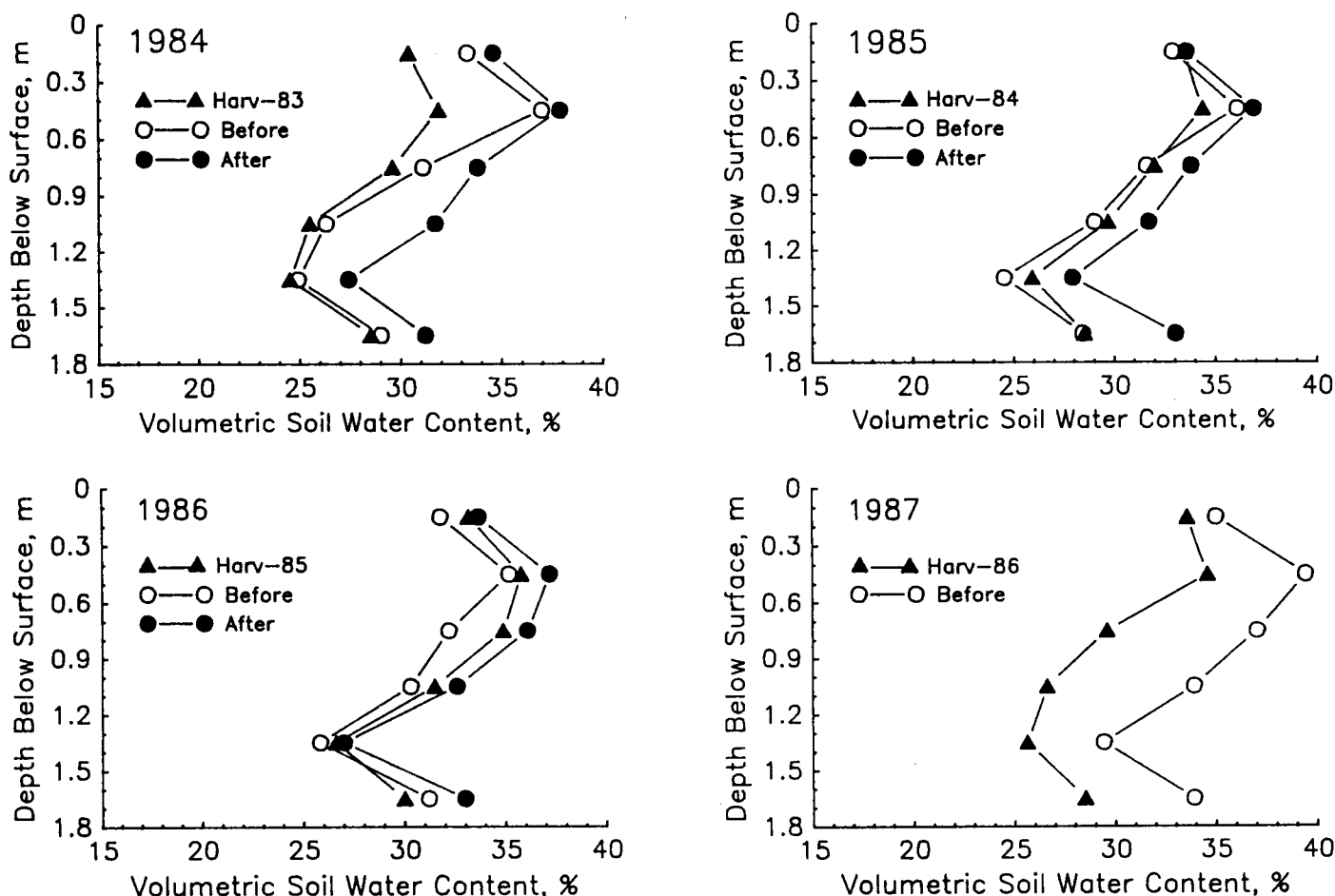


Figure 2—Average soil water content to 1.8 m (6 ft) deep after fall grain sorghum harvest, and before and after preplant irrigation applications. Bushland, TX 1984-87 (0.3 m = 1 ft).

TABLE 4. Available soil water to 1.8 m depth, irrigation water applied, irrigation intake, irrigation application efficiency and irrigation storage efficiency, for preplant applications, Bushland, TX (1984-86)

Treatment	Available soil water*			Preplant irrigation			
	After harvest	Before preplant	After preplant	Applied	Intake	Irrigation application efficiency	Irrigation storage efficiency
	mm (in.)			mm (in.)		%	
1984	163 (6.42)	197 (7.76)	243 (9.57)				
T-1				183 (7.20) a†	150 (5.90) a†	82 a†	31 a†
T-2				183 (7.20) a	158 (6.22) a	86 a	29 a
T-3				183 (7.20) a	153 (6.02) a	84 a	30 a
1985	204 (7.99)	198 (7.80)	243 (9.57)				
T-1				230 (9.06) a	220 (8.66) a	95 a	20 b
T-2				196 (7.72) b	178 (7.01) b	91 a	25 a
T-3				207 (8.15) ab	188 (7.40) b	91 a	24 a
1986	229 (9.02)	218 (8.58)	253 (9.96)				
T-1				196 (7.72) a	144 (5.67) ab	74 a	24 a
T-2				196 (7.72) a	161 (6.33) a	82 a	22 a
T-3				196 (7.72) a	140 (5.51) b	72 a	25 a
Mean	199 (7.83)	204 (8.03)	246 (9.68)				
T-1				203 (7.99) a	171 (6.73) a	84 a	25 a
T-2				192 (7.56) a	166 (6.53) a	86 a	25 a
T-3				195 (7.68) a	160 (6.30) a	82 a	26 a

* Available storage capacity 0 to 1.8 m = 250 mm (0 to 6 ft = 9.8 in.)
0 to 1.2 m = 180 mm (0 to 4 ft = 7.2 in.).

† Column values for individual years followed by the same letter are not significantly different at the 5% level according to Duncan's Multiple range test.

irrigation should be similar to those for dryland sorghum. We reviewed sorghum planting dates for a long-term dryland study at Bushland involving a wheat-sorghum-fallow rotation (O. R. Jones, unpublished data). Planting dates for a 30-year period (1959 through 1988) were plotted in a cumulative probability curve (fig. 3). Planting dates ranged from 24 May to 2 July, with a 50% probability date of 11 June. In 50% of the years, planting occurred between 6 June and 18 June; and in 80% of the years, planting occurred between 31 May and 22 June. Thus, the delayed 22 June planting in 1984 would not be expected to occur more than 20% of the time.

From these results, it is obvious that the management of the soil surface in a flat condition from fall into spring does not guarantee adequate seed zone water content for sorghum crop establishment without a preplant irrigation. Timely spring rainfall is needed to rewet the seed zone to the 100-mm (4-in.) depth. However, a flat soil surface increases the likelihood of success in establishing a sorghum crop without a preplant irrigation. Rewetting the seed zone of a flat surface should require less precipitation than for raised beds that are normally formed with dry surface soil. Also, intense rainfall from short duration spring thunderstorms tends to run off from beds into furrows, with only limited wetting of the beds. In order to successfully establish a crop without a preplant irrigation, the time of planting must be flexible enough to allow for annual shifts in the time of May-June rainfall occurrences. If planting is delayed until mid-June, a shorter growing season may limit grain yield.

IRRIGATION WATER USE, GRAIN YIELD, AND WATER USE EFFICIENCY

Water use data and grain yield are presented in Tables 5 and 6. In 1984, two seasonal irrigations were applied to the PP treatment and three seasonal irrigations were applied to the No-PP treatment. The No-PP treatment received a 7 September application (Table 2) for grain filling because of later development from delayed planting. The No-PP treatments yielded about 1000 kg/ha (900 lb/ac) or 14 to 20% less than did the PP treatment because of delayed planting. An early freeze prior to physiological maturity on 30 September 1984, (four weeks earlier than average) caused some yield reduction from delayed planting by reducing seed-weight 12% from 27 to 24 mg/seed (1050 to 1180 seed/oz). In a previous study at Bushland (Allen et al., 1969), a 19-day planting delay from 22 May to 10 June reduced grain yields by 7% for a similar maturity sorghum hybrid.

In 1985, four seasonal irrigations were applied to both irrigation treatments on the same dates since planting times were the same. Grain yields for the PP treatments ranged from 200 to 460 kg/ha (180 to 410 lb/acre) less than on No-PP treatments in 1985. Nitrogen deficiency symptoms were observed on the PP treatments and the yield reduction apparently was the result of N leaching from deep percolation associated with the relatively high intake of 180 to 220 mm (7 to 8.7 in.) during the preplant irrigation.

In 1986, three seasonal irrigations were applied to the PP treatment and two irrigations were applied to the No-PP treatment. Total irrigation intake on the PP treatments was

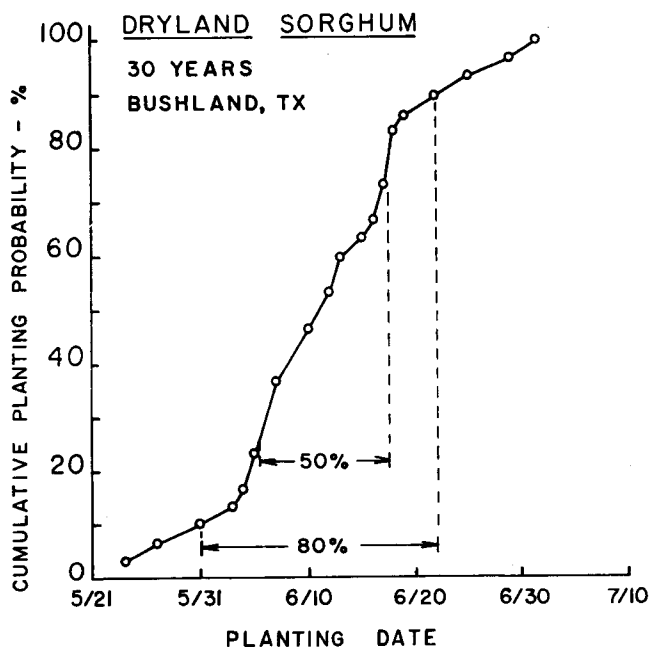


Figure 3—Dryland grain sorghum planting date plotted vs. cumulative planting probability during 1959 through 1988. Planting occurred on 19 dates during the 30-year period. Dashed lines indicate time intervals when 50% and 80% of the planting dates occurred (O. R. Jones, unpublished data).

nearly twice that of the No-PP treatments. Total water use was about 30% greater for the PP treatments. The greater intake and water use on PP treatments was attributed to both deep percolation loss from the preplant application and from the longer growth stage for water use. Timely planting contributed to the yield increase (about 13%) for the PP treatment. However, WUE was about 20% greater for the No-PP treatments because of reduced seasonal water use.

In 1987, a preplant irrigation was not needed as already discussed. Two seasonal irrigations were applied during July, then August-September rainfall (about twice the average) supplied the remaining seasonal water use needs.

On the average during the four years, sweep tillage (T-2) had a small but consistent effect on increasing irrigation intake and seasonal water use on No-PP treatments. As yields did not increase correspondingly for the increased intake on the T-2 treatment, WUE was also lower.

During 1984 to 1986, the PP irrigation treatment averaged 483-mm (19-in.) total irrigation water intake, which was 70% more than the 280 mm (11 in.) for the No-PP treatment. Profile storage efficiencies from preplant irrigation intake ranged from 20 to 31%. Seasonal water use, including rainfall and profile depletion, averaged 785 mm (31 in.) for the PP treatment which was 24% more than the 630 mm (25 in.) for the No-PP treatment. The PP treatment averaged only 10% more grain yield, resulting in

TABLE 5. Seasonal rainfall, irrigation applied, irrigation intake, seasonal water use, grain yield and total water use efficiency, Bushland, TX (1984-87) (metric units)

Treatment	Seasonal rainfall	Irrigation applied		Irrigation intake		Seasonal water use		Grain yield		WUE	
		PP	No-P	PP	No-PP	PP	No-PP	PP	No-PP	PP	No-PP
	(mm)	(mm)		(mm)		(mm)		(kg/ ha)		(kg/m ³)	
1984											
T-1 Conventional	255	565	395	420 a*	225 b*	790 a*	705 b*	7560 a*	6680 b	0.96 ab*	0.95 ab*
T-2 Sweep		565	395	470 a	260 b	790 a	720 b	7750 a	6340 b	0.98 a	0.88 b
T-3 Chisel-chop		565	395	410 a	225 b	800 a	660 b	7570 a	6270 b	0.95 ab	0.95 ab
1985											
T-1 Conventional	350	730	500	640 a	400 b	825 a	605 b	6140 a	6600 a	0.74 c	1.09 a
T-2 Sweep		710	500	585 a	420 b	765 a	655 b	6310 a	6530 a	0.82 c	0.99 b
T-3 Chisel-chop		710	500	595 a	390 b	750 a	610 b	5900 a	6260 a	0.79 c	1.02 ab
1986											
T-1 Conventional	390	583	232	392 a	208 b	770 a	586 b	8270 a	7500 bc	1.07 b	1.28 a
T-2 Sweep		583	232	413 a	214 b	773 a	592 b	8320 a	7100 c	1.08 b	1.20 a
T-3 Chisel-chop		583	232	417 a	180 b	807 a	558 b	7830 ab	6980 c	0.97 c	1.25 a
MEAN (1984-86)											
T-1 Conventional	330	626	375	484 a	278 b	795 a	632 b	7320 a	6930 ab	0.92 c	1.11 a
T-2 Sweep		620	375	490 a	298 b	776 a	655 b	7460 a	6660 b	0.96 bc	1.02 ab
T-3 Chisel-chop		620	375	474 a	265 b	785 a	610 b	7100 a	6500 b	0.90 c	1.07 a
1987											
T-1 Conventional	410		220		165 a		619 a		6760 a		1.10 a
T-2 Sweep			220		189 a		654 a		6405 a		0.98 b
T-3 Chisel-chop			220		167 a		613 a		6410 a		1.05 ab
MEAN (1984-87)											
T-1 Conventional	350		337		250 a		629 a		6890 a		1.10 a
T-2 Sweep			337		270 a		655 a		6590 a		1.01 a
T-3 Chisel-chop			337		240 a		610 a		6480 a		1.07 a
OVERALL MEAN	350	622	337	483	253	785	631	7290	6650	0.93	1.06

* Values for separate factors in individual years followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

TABLE 6. Seasonal rainfall, irrigation applied, irrigation intake, seasonal water use, grain yield and total water use efficiency, Bushland, TX (1984-87) (English units)

Treatment	Seasonal rainfall	Irrigation applied		Irrigation intake		Seasonal water use		Grain yield		WUE	
		PP	No-P	PP	No-PP	PP	No-PP	PP	No-PP	PP	No-PP
	(in.)	(in.)		(in.)		(lb/ac)		(lb/ac)		(lb/ac-in.)	
1984											
T-1 Conventional	10.0	22.2	15.6	16.5 a	8.9 b	31.1 a	27.8 b	6730 a	5945 b	216 ab	214 ab
T-2 Sweep		22.2	15.6	18.5 a	10.2 b	31.1 a	28.3 b	6900 a	5640 b	222 a	199 b
T-3 Chisel-chop		22.2	15.6	16.1 a	8.9 b	31.5 a	26.0 b	6740 a	5580 b	214 ab	215 ab
1985											
T-1 Conventional	13.8	28.7	19.7	25.2 a	15.7 b	32.5 a	23.8 b	5460 a	5870 a	168 c	247 a
T-2 Sweep		28.0	19.7	23.0 a	16.5 b	30.1 a	25.8 b	5615 a	5810 a	193 c	225 b
T-3 Chisel-chop		28.0	19.7	23.4 a	15.4 b	29.5 a	24.0 b	5250 a	5570 a	178 c	232 ab
1986											
T-1 Conventional	15.4	23.0	9.1	15.4 a	8.2 b	30.3 a	23.1 b	7360 a	6675 bc	242 b	289 a
T-2 Sweep		23.0	9.1	16.3 a	8.4 b	30.4 a	23.3 b	7405 a	6320 c	244 b	271 a
T-3 Chisel-chop		23.0	9.1	16.4 a	7.1 b	31.8 a	22.0 b	6970 ab	6210 c	219 c	282 a
MEAN (1984-86)											
T-1 Conventional	13.0	24.6	14.8	19.1 a	10.9 b	31.3 a	24.9 b	6515 a	6170 ab	208 c	248 a
T-2 Sweep		24.4	14.8	19.3 a	11.7 b	30.6 a	25.8 b	6640 a	5930 b	217 bc	230 ab
T-3 Chisel-chop		24.4	14.8	18.7 a	10.4 b	30.9 a	24.0 b	6320 a	5785 b	205 c	241 a
1987											
T-1 Conventional	16.1		8.7		6.5 a		24.4 a		6015 a		247 a
T-2 Sweep			8.7		7.4 a		25.7 a		5700 a		222 b
T-3 Chisel-chop			8.7		6.6 a		24.1 a		5705 a		237 ab
MEAN (1984-87)											
T-1 Conventional	13.8		13.3		9.8 a		24.8 a		6130 a		247 a
T-2 Sweep			13.3		10.6 a		25.8 a		5865 a		227 a
T-3 Chisel-chop			13.3		9.4 a		24.0 a		5765 a		240 a
OVERALL MEAN	13.8	24.5	13.3	19.0	10.0	31.0	24.9	6490	5920	209	238

* Values for separate factors in individual years followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

a significantly lower (12%) total WUE compared with the No-PP treatment. In order to compare the average cost versus benefit of the extra irrigation water pumped and applied with preplant irrigations during 1984-86, the following representative pumping plant conditions as described by New (1986) are defined: 98-m (320-ft) pump lift, 22% natural gas powered engine efficiency, 65% pump and gearhead efficiency, $\$0.043/\text{m}^3$ ($\$0.004/\text{ft}^3$) natural gas cost, and a $\$0.09/\text{kg}$ ($\$0.04/\text{lb}$) grain sorghum price. The 245-mm (9.6-in.) average depth of extra irrigation applied to PP treatments cost $\$64.38/\text{ha}$ ($\$26.00/\text{acre}$). The 600 kg/ha (535 lb/acre) extra grain produced was worth $\$54.00$. Thus, extra fuel cost exceeded the value of increased grain yield by $\$10.38/\text{ha}$ ($\$4.20/\text{acre}$).

CONCLUSIONS

On the fine-textured soils of the Southern High Plains, the application of a preplant irrigation for grain sorghum production can substantially increase the amount of irrigation water used to produce the crop. A 10% increase in grain yield from preplant irrigation did not justify the 70% increase [280 to 483 mm (11 to 19 in.)] in irrigation water use; which cost about $\$10.00/\text{ha}$ ($\$4.00/\text{ac}$) more for pumping than the extra grain was worth.

The results emphasize the importance of precipitation near planting time for stand establishment without preplant

irrigation. The use of reduced tillage was not adequate to assure adequate seed zone soil water content to 10 cm (4 in.) deep for stand establishment without timely precipitation. In order to successfully establish a crop without a preplant irrigation, the time of planting must be flexible to allow for annual shifts in May-June rainfall occurrences. If planting is delayed until mid-June, grain yield may be reduced. The use of flat-tillage management for planting without a preplant irrigation increases the likelihood of stand establishment because less precipitation is required to wet a flat soil surface than on rounded beds that shed precipitation.

Tillage method had no effect on four-year average sorghum grain yield and only a small effect on irrigation water intake, seasonal water use, or water use efficiency.

REFERENCES

- Allen, R.R., J.T. Musick, F.O. Wood and D.A. Dusek. 1969. Grain sorghum yield response to row spacing in relation to seeding date, days to maturity, and irrigation level in the Texas Panhandle. Texas Agric. Exp. Stn. Prog. Rep. PR-2697.
- Musick, J.T., W.H. Sletten and D.A. Dusek. 1971. Preseason irrigation of grain sorghum in the Southern High Plains. *Transactions of the ASAE* 14(1): 93-97.

- Musick, J.T. 1973. Supplementing rainfall with limited irrigation minimum tillage systems. Proc. USDA-SCS – Texas Tech University Conservation Workshop on *Maximizing rainfall in semi-arid areas for plant production*. Lubbock.
- . 1984. Irrigation water management research – Southern Ogallala Region. *Proc. Ogallala aquifer symp. II*, 98-122. Lubbock, TX.
- . 1985. Strategies and techniques for water conservation with limited and full irrigation in the Southern Great Plains. Proc. USDA-SCS Workshop on *Planning and managing water conservation systems in the Great Plains States*, Lincoln, NE.
- . 1987. Preplant irrigations in the Southern High Plains – A review. ASAE Paper No. 87-2558. St. Joseph, MI: ASAE.
- New, L.L. 1986. Pumping plant efficiency and irrigation costs. Texas Agric. Ext. Serv. Leaflet L-2218.
- Undersander, D.J. and Cecil Regier. 1988. Effect of tillage and furrow irrigation timing on efficiency of preplant irrigation. *Irrig. Sci.* 9: 57-67.
- Unger, P.W. and F.B. Pringle. 1981. Pullman soils: Distribution, importance, variability, and management. Texas Agric. Exp. Stn. Bull. 1372.